The Patent Office

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP9 1RH

GB99/765

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed [signature]

Dated 1/4/99

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Patents Form 1/77

9805271.5

The Patent Office

MAR98 E345169-1 D00735
01/7700 25.00 - 9805271.5

177

Patents Act 1977
(Rule 16) 13 MAR 1998

THE PATENT OFFICE
G
13 MAR 1998
NEWPORT
£25.00

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
Gwent NP9 1RH

1.	Your reference	DIH/RJB/P99466GB
2.	Patent application number *(The Patent Office will fill in this part)*	9805271.5
3.	Full name, address and postcode of the or of each applicant (*underline all surnames*)	**The University of Liverpool,** Senate House, Abercromby Square, Liverpool, L69 3BX.
	Patents ADP number (*if you know it*)	
	If the applicant is a corporate body, give the country/state of its incorporation	ENGLAND. 00891184001
4.	Title of the invention	FIELD EMISSION CATHODE AND FIELD EMISSION DISPLAY.
5.	Name of your agent (*if you have one*)	**W.P.THOMPSON & CO.**
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Coopers Building, Church Street, Liverpool, L1 3AB.
	Patents ADP number *(if you know it)*	0000158001 ✓

6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country	Priority application number *(if you know it)*	Date of filing *(Day/month/year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		Number of earlier application	Date of filing *(Day/month/year)*
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'yes' if:* *a) any applicant named in part 3is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	YES		

Patents Form 1/77

9. Enter then number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	8
Claims(s)	
Abstract	
Drawing(s)	1

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(Please specify)*	

11. I/We request the grant of a patent on the basis of this application

Signature W.P. Thompson & Co. Date 12/03/98

W.P.THOMPSON & CO.

12. Name and daytime telephone number of person to contact in the United Kingdom

R.J. BARTLE.
0151-709-3961

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 01645 500505*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

DESCRIPTION

FIELD EMISSION CATHODE AND FIELD EMISSION DISPLAY

The present invention is concerned with field emission electrodes and with field emission displays.

A great deal of research effort has been devoted in recent years to developing a display which can replace the conventional cathode ray tube (CRT). Shortcomings of the CRT include its weight and bulk, and also its requirement for relatively high input power. The CRT is also unsuited to use in large area displays - eg. in stadia and in small displays for laptops, watches etc.

The liquid crystal display (LCD) provides an alternative which is not subject to some of the disadvantages of the CRT. It can be manufactured in flat panel format, and used both in miniature displays and in larger displays, eg. in wide format television sets. However, LCD displays suffer from disadvantages of their own, particularly with regard to display brightness.

A promising alternative to both LCDs and CRTs is the field emission display (FED). FEDs offer the prospect of flat panel displays which are superior to LCD screens in brightness, colour rendition, response time and operating temperature range.

In the FED, electrons are released from a cathode by field emission (rather than by thermionic emission, as in the CRT) and accelerated toward an anode which is maintained at a positive potential (1 kV is typical for known displays). The electrons impinge on phosphor pixels which are thereby caused

to luminesce, providing the display. To generate the field needed for release of electrons, a matrix of switchable row and column electrodes is provided, in addition to the anode, and in this way pixels can be individually addressed.

Known FEDs utilise cathodes having on their surface an array of microscopic pointed elements known as Spindt tips, formed of Mo or Si. The tips are very sharp- having radii of the order of 20nm - thereby providing large local electric fields to cause field emission. This is necessary because in the materials of such known cathodes the work function (the energy needed to release an electron from the cathode) is relatively high - of the order of 5eV. These known cathodes are not straightforward to manufacture and suffer from reliability problems due to erosion of the field tips.

An alternative approach which has been proposed is to provide a cathode lacking Spindt tips but formed of material having low (or even negative) electron affinity. Electrons may be released from such a material by relatively small electric fields.

There is in almost all such field emission systems the need to electrically condition the film forming the cathode before low threshold emission is possible. Diamond like carbon (DLC) films have given high emission, particularly when doped with nitrogen. The latter has provided the lowest threshold reported. The nature of the bonding is thought to be an important factor with diamond-like sp^3 bonds being appropriate for producing the energy levels associated with a low electron affinity.

Current understanding of the main features of the emission processes is

incomplete, but it is believed that the density of sp^3 bonds and the presence of hydrogen are important. An alternative model is based on a dual process which involves electron heating in the DLC conduction band due to its internal electric field and emission over the relatively low surface potential barrier (electron affinity). Nitrogen acts as a donor fostering the formation of a high field depletion region.

Although DLC film cathodes have hitherto been considered the most promising candidate, the results have not been sufficiently impressive for displays based on such materials to be considered an immediate replacement for the CRT and LCD.

A need therefore exists for a field emission cathode having improved properties, particularly for use in field emission displays. It is desirable that such a cathode should have low electron affinity, or perhaps negative electron affinity. A high density of free electrons is also desirable - a characteristic not usually compatible with negative electron affinity.

In accordance with a first aspect of the present invention, there is provided a field emission cathode comprising polymer material.

The polymer material forms a field emission surface. This can have low or negative electron affinity.

The inventors have fortuitously (and most unexpectedly) discovered that polymer materials can be manufactured giving high electron emission. Polymer materials can be formed by known techniques into uniform cathodes, which may be large in area, and can be highly stable. Exclusion of oxygen is

considered important for the stability of the material.

It is particularly preferred that the polymer is a conjugated polymer material. Conjugated polymers typically have the desired high density of free electrons.

Such materials are known for other applications in electronics, which utilise semiconductor type properties of certain conjugated polymers. The usual applications proposed for conjugated polymers - eg. in light emitting structures, photocopiers, photodetectors and thin film transistors - do not require the material to have low electron affinity, and it is believed that this property of such materials has not hitherto been researched. The present inventors have found that some such polymeric materials are capable of producing very high steady state field emission currents with the threshold field needed to initiate field emission being smaller than for any other material so far reported.

It is especially preferred that the polymer material is a polythiophene. Polyalklythiophene is currently the preferred material.

The cathode may be flat. The polymer material may take the form of a thin film on a substrate.

The polymer material is preferably spun from a liquid source or is evaporated in a vacuum onto a substrate, a technique which can produce a large area cathode. A light and economical cathode can be produced in this way.

The polymer material should have a low barrier to electrons of the

substrate on which it is formed.

The polymer material may be doped with an electron donor material. The electron donor may be nitrogen (known to reduce the threshold field in diamond-like carbon). In fact, un-doped polymers have relatively low number of electrons but emit them very efficiently. This leaves a great deal of scope for improvement by doping.

The polymer material may have grain boundaries serving to concentrate the electric field. In this way, field emission is promoted. In a preferred structure, the polymer material forms a film on a substrate comprising microcrystalline silicon. The grain boundaries at the polysilicon surface trap large numbers of electrons as the surface becomes more n type, and so are able to concentrate the field at these points, promoting increased emission from the polymer film.

A polycrystalline polymer material may be used in the field emission cathode. Grain boundaries in such materials offset to some degree the problem of low electron mobility.

In accordance with a second aspect of the present invention, there is a field emission display having a cathode in accordance with the first aspect of the invention.

A specific embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawing, which is a schematic cross section through a field effect display constructed in

accordance with the present invention.

In the illustrated FED, the field emission cathode is a flat film 2 of polymer material disposed on a conducting substrate 3 maintained at low electrical potential. An anode 4 is provided in front of the cathode, and bears pixels 5 of a material which emits light when struck by energetic electrodes, to produce the display. The anode may consist of a light emitting phosphor on glass. Between the anode and the cathode is a grid 6 which can be selectively positively charged. The space 7 between the anode and the cathode is a vacuum.

In operation, selected regions of the grid 6 are charged positively (relative to the cathode) producing the field necessary for field emission of electrons from corresponding regions of the cathode. These electrons are accelerated through the grid by the electric field due to the anode 4, and strike the anode causing it to emit light in selected regions of the screen.

Polyalkylthiophene is considered a suitable material for the cathode. The inventors have carried out an experimental study of space charge limited currents in polythiophenes. There is substantial trapping at discrete levels, and the free carrier density, usually holes, is at a lower concentration than the density of trapped holes. For such a material to be an efficient emitter of electrons there must be some alignment of the conduction band with the substrate conductor that promotes the high injection of electrons in the film, swamping the very low hole concentration in the film and limiting the recombination. It is believed that the vacuum level is simultaneously reduced

so that such electrons find their way very easily into the vacuum. Early analysis suggests that relatively low field strengths are needed at the back of the film to promote the injection, and field emission measurements indicate the presence of space charge limited current due to electrons, mainly trapped in acceptor-like states in the top half of the energy gap. The states themselves may be associated with grain boundaries. A further factor is the orientation of the molecules. It is known that when conduction occurs down the molecule, mobility might be high but for the limiting value of the conjugation length. For this reason highest mobilities in thin film transistors are seen normal to the molecular axis, in relatively short molecules that can be made to stand up from the surface. There is some hope on the basis of quantum mechanical calculations that if longer molecules could be self assembled, so that they stand vertically from the surface, then much higher mobilities could be attained.

Mobility is important because all the evidence to date points to the emission being controlled by space charge limited current in the film which is linearly related to the carrier mobility. The high emission seen in polymers may be enhanced by the presence of microscopic irregularities. SEM pictures of the various polymer films that have demonstrated high stable field emission are largely featureless but have small ridged structures, perhaps associated with sites of solvent evaporation. These ridges may enhance the emission. The high emission that has been observed is not thought to be stimulated by field variations around grain boundaries at the conducting substrate. The use of a well controlled polycrystalline substrate, of known crystal size, at the back of

the polymer film might well produce even more efficient field emission. It is well known that in polysilicon, for example, when relatively lightly doped, there is an intensification of the field due to the combined effect of grain boundary traps and the need for the conduction band to re-equilibrate itself with the grains over a finite distance.

FIG. 1